Earth Resources Satellite Data Applications Series

The Landsat Story

Module U-2 January 1980

A Users Assistance Publication prepared by the National Aeronautics and Space Administration, Office of Space and Terrestrial Applications

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Preface

With the increasing interest in Landsat data by the private and public sectors, the availability of pertinent information for potential users is of vital concern. Introduction of the Earth Resources Satellite Data Applications Series of publications is directed toward bridging that gap which often arises between fast-paced technology development and the availability of practical results to the user community. This series of publications is intended to be responsive to needs of the public and private sectors for practical guidance to the disciplinary, functional, and educational uses of Earth Resources Satellite data.

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Earth Resources Satellite
Data Applications Series

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Introduction

In 1966, NASA formalized plans for an Earth Resources Survey Program which was intended to increase the practical benefits of space research by developing satellites devoted specifically to surveys of the Earth's resources. In July, 1972, the first Earth Resources Technology Satellite, ERTS 1, (later renamed "Landsat 1") began to acquire images of the Earth's surface. Since then, two more Landsats have been launched, and the first member of this satellite series has been deactivated. At present, plans are being made to launch a fourth Landsat which will acquire data and foster products of a more operational nature than provided by its predecessors.

A real value of Earth resources satellite data for both the public and private sectors lies in the availability of data products to all users at reasonable cost. However, the availability of data alone does not promote its effective use. NASA is producing a series of user assistance publications as an aid for those who must decide if, how, and when to use Earth resources satellite data and for those who will actually analyze and utilize the data. *The Landsat Story* is one of these publications; others are described in the *Guide to Publications* (Module U-1) of this series.

The intent of *The Landsat Story* is to provide an introductory, yet comprehensive review of the various Landsat program elements which are relevant to user participation. It also identifies sources for additional information and assistance where potential users may acquire more details and further guidance in using Landsat data.

The Landsat Program

Development of the Landsat series of satellites began in the late sixties. In July, 1972, the first satellite in the Earth Resources Technology Satellite (ERTS) Program was launched. In January, 1975, the program was redesignated as the "Landsat Program" to emphasize the primary area of interest, the resources of land masses.

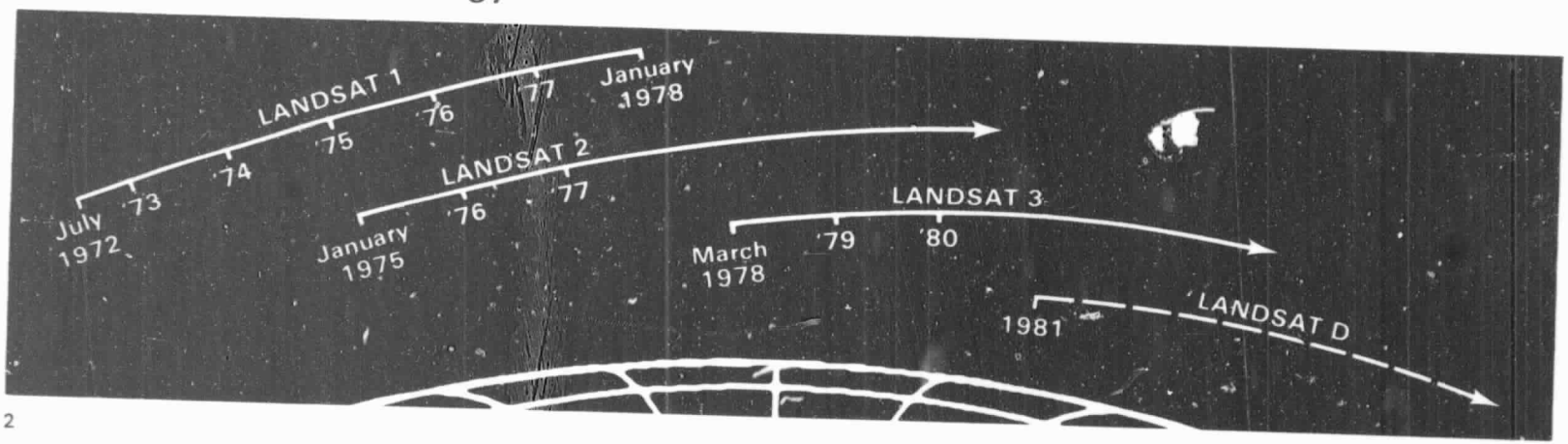
Based upon technology developed for the early weather satellites of the 1960s, interest in the Landsat Program arose from an increasing national concern for environmental quality and natural resources issues. The basic mission objective was to develop a satellite to survey the Earth's land surface on a systematic, repetitive, and continuing basis.

The launch and operation of three successful experimental Landsats in July 1972, January 1975, and March 1978 introduced new capabilities for acquiring, analyzing, and utilizing Earth resources information. The usefulness of Landsat data has favorably impacted activities of both public and private sectors within the United States and foreign countries. In view of Landsat's demonstrated potential, Congress has authorized the launching of the fourth satellite in the series, Landsat D, thus assuring program continuation through the early 1980s. (In the Landsat series, satellites that are approved, planned or under development are designated by alphabetical letters, such as Landsat "D." Once the satellite has successfully achieved orbit, the letter is replaced by the next number in the series; e.g., Landsat "4.")

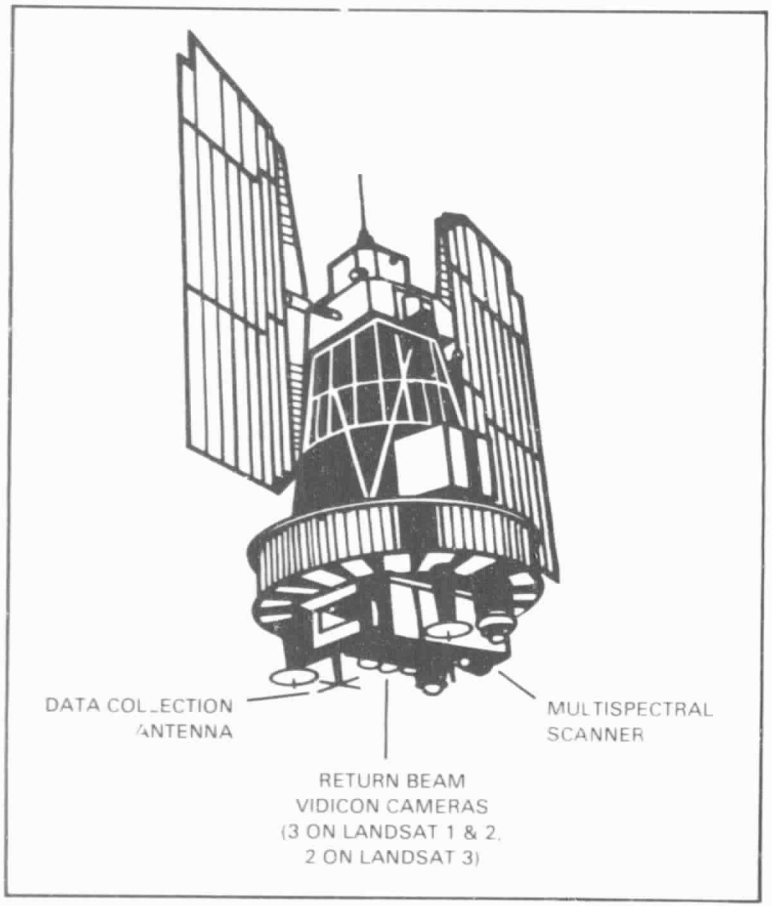
The current series of Landsats (1, 2, and 3) features the same *platform* configuration and similar *sensor systems*. Although Landsat D will carry a duplicate of one of the current sensors, it will have a completely different platform design and a new sensor system which will provide improvements in *spectral coverage* and *spatial resolution*.

The past eight years of the Landsat program have encompassed a period of technological advancement, data collection experi-

Landsat Program Chronology



Platform Configuration, Landsats 1, 2, 3



mentation, and data applications demonstration. The utility of satellite imagery and derived products has been of significant value to many users engaged in natural resource and environmental activities. Others have appreciated the potential usefulness of synoptic, repetitive, and systematic imagery provided by Landsat but are awaiting for improved sensor capabilities to satisfy more demanding applications.

Platform - Refers to the basic framework of the orbiting satellite which houses sensing devices and associated equipment. Similarly, airplanes and balloons have been considered as platforms for carrying aerial cameras in the atmosphere.

Sensor System - An integrated set of equipment and devices which sense, collect, and store information received from the Earth's surface.

Spectral Coverage - The extent and portions of the electromagnetic spectrum for which a sensor system is designed. These portions of the spectrum are commonly referred to as "bands" or "channels" and are defined by upper and lower wavelength limits in units of micrometers.

Spatial Resolution - In general, the minimum linear dimension of a feature on the Earth's surface where electromagnetic reflectance/radiation can be recorded by a (Landsat) sensor system. (Notable exceptions include small bright objects and high contrast linear features). In a scanner system, resolution is derived from the instantaneous field of view from which reflectance/radiation is being recorded, and is measured as a ground area in acres or hectares.

The Landsat System

The Landsat system has the unique capability, offered only by satellite platforms, to observe continually and repetitively most places on the Earth's surface. By selecting the appropriate orbital parameters and employing specialized sensor systems, the current Landsats can acquire images of very large areas anywhere in the world (except at the poles). Moreover, the resultant images can be from a single spectral band or from several spectral bands (multi-spectral imagery). Repetitive coverage not only increases the probability of cloud-free images of a given area, but also permits the detection of ground surface changes over time intervals of days and weeks, or longer.

In addition, current Landsats have a capability to receive data transmitted from land-based data collection terminals for relay to designated ground stations whenever the sender and receiver points are in a line-of-sight relationship with the satellite. This radio-relay link provides environmental and resource-related data from remotely located ground sensors to receiving stations for delivery to investigators in various agencies.

The Landsat system is comprised of two segments:

- The **space segment**, consisting of satellite and data acquisition components.
- The **ground data handling segment**, consisting of satellite control, data receipt, data processing, and dissemination functions.

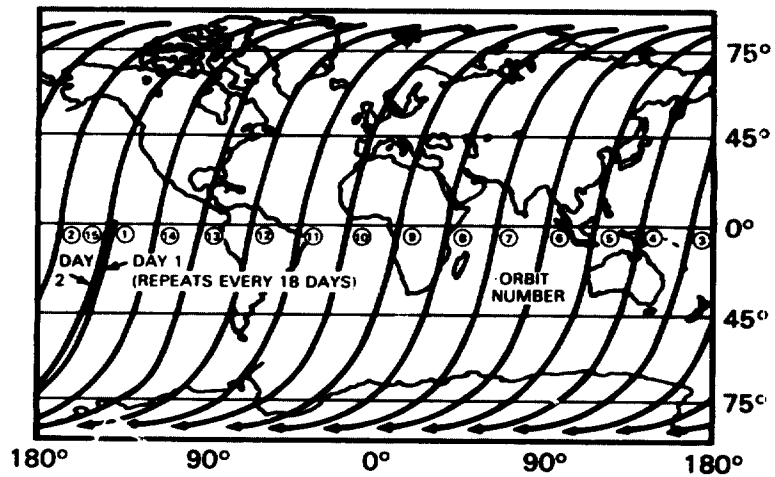
The Space Segment

The Landsat 1, 2, and 3 spacecraft weigh about one ton each, are butterfly-shaped, and measure approximately 1.5 x 3 meters (5 x 10 feet), without solar panels. The payload includes a multispectral scanner, a return beam vidicon camera, and a data collection/relay system.

Although launched with a planned design life of one year, Landsat 1 functioned well for over five years and returned data for 300,000 images of the Earth's surface from space. Landsats 2 and 3 are currently operating and are continuing to provide data.

In order to provide wide area and repetitive coverage of the Earth's surface, Landsat satellites are placed in a near polar, circular Earth orbit at an altitude of 920 km (570 miles). They circle the Earth in 103 minutes and complete 14 orbits per day. Because of the rotation of the Earth under the orbiting satellite, each pass has a ground trace that is displaced 2,875 km (1,785 miles) west of the previous one—measured at the equator.

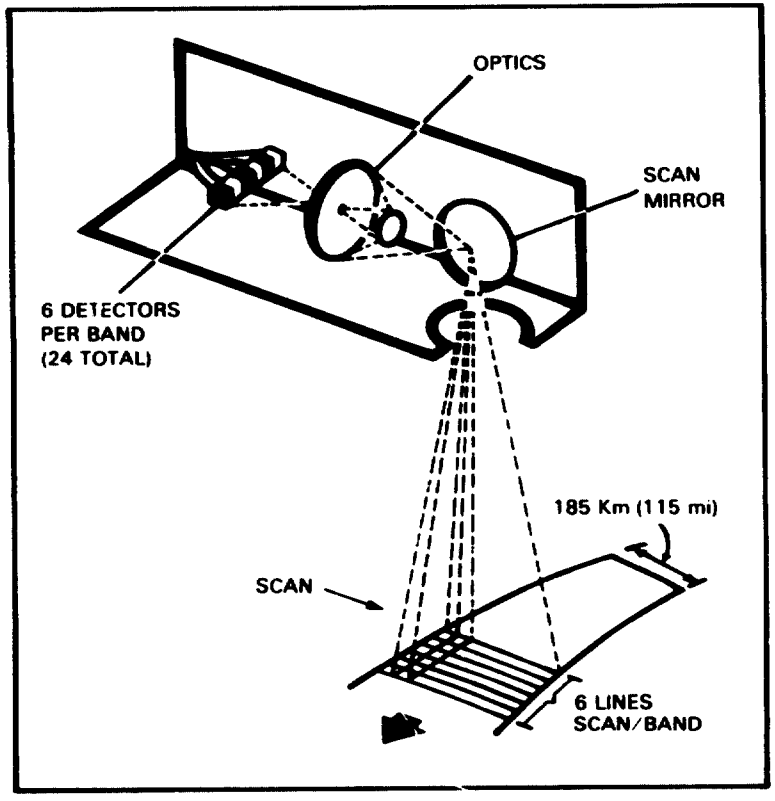
Typical Landsat Daily Ground Trace (Daylight Passes Only)



Every day the spacecraft begins a new cycle of passes which are displaced 160 km (99 miles) from the previous day's cycle. These coverage gaps caused by the Earth's rotation are filled in progressively, day by day, by the 185 km (115 miles) ground swath of the sensors. In this manner, Landsat views the entire Earth every 18 days except for the polar regions.

Taking advantage of this 18-day period, Landsats 2 and 3 have been placed in orbit so that one of them will pass over a given place on Earth about once every nine days. Moreover, the orbits of these spacecraft are *sun-synchronous*, which means that each Landsat passes over the same point on the Earth at essentially the same local time every 18 days. Therefore, for a given place, the sun angle will remain nearly the same for several weeks, providing repeatable illumination and shadows. However, as the seasons change, the solar elevation angles and lighting conditions will also vary. The sun-synchronous orbit feature is very advantageous because constant illumination is helpful in the detection of changes in a scene, and low/high sun

MSS Scanning Arrangement



angles are useful in studying landscape and terrain features.

The **multispectral scanner (MSS)** is one of the Landsat sensors. In Landsats 2 and 3, the MSS responds to light reflected from the Earth in four spectral bands. Radiation received from the Earth is reflected to fiber optic bundles within the MSS by a swinging mirror. These "light pipes" then conduct the radiance to spectrally-sensitive detectors. As the mirror swings perpendicular to the ground path of the satellite, it scans a line of 185 km (115 miles) on the ground. The forward motion of the spacecraft constantly brings the Earth's surface under the scanner's view—thus producing a continuous strip of imagery. During the data processing phase, the MSS imagery is transformed into segments with ten percent overlap and an area coverage of approximately 185 x 185 km (115 miles), which is compatible with image frames from the *return beam vidicon camera* (discussed below).

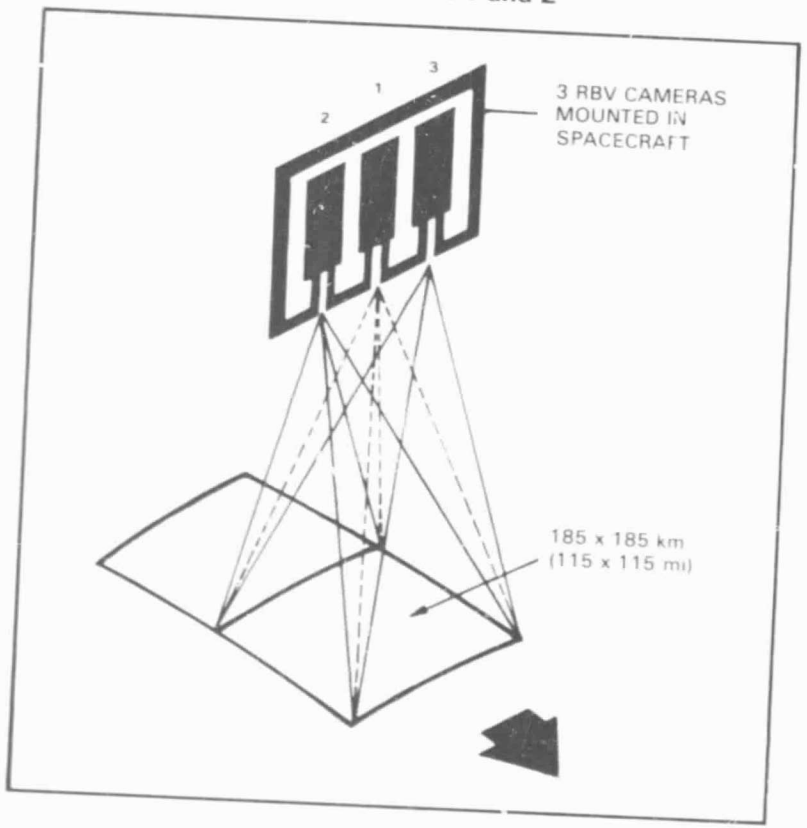
As the mirror scans the ground, radiation is received and recorded simultaneously in the four wavelength bands from 0.5-1.1 micrometers. Six detectors in each of these bands sense the received radiation. The detectors' outputs are then sampled, encoded, and formatted for transmission to ground stations.

Landsat sensors record only a small portion of the total radiation reflected or emitted from the Earth's surface. However, the visible and infrared spectra carry most of the information of interest in surveying natural resources and the environment.

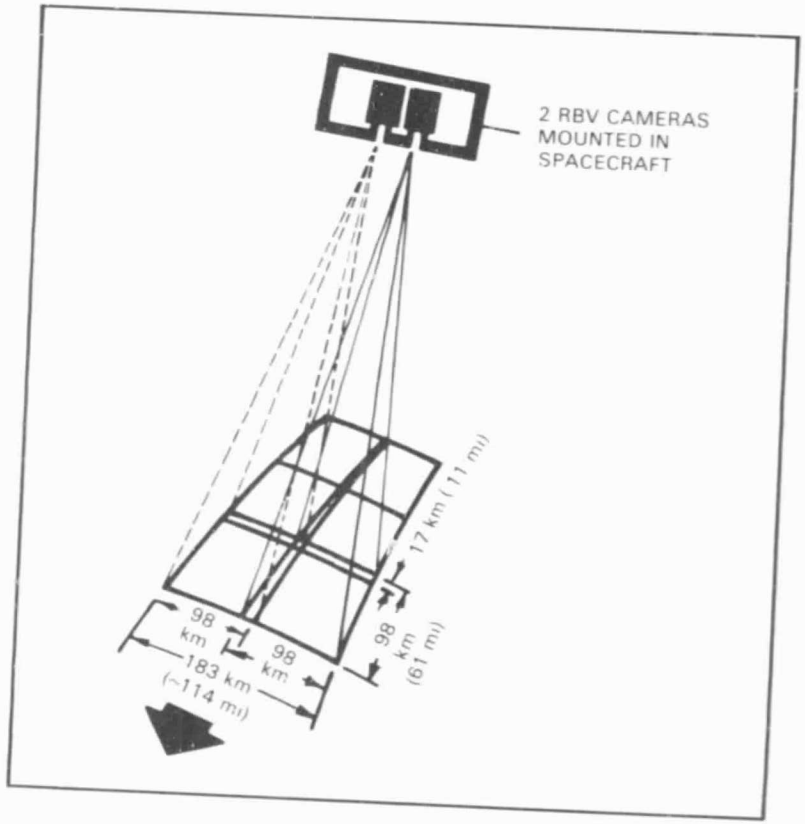
A second generation multispectral scanner is planned for Landsat D, the fourth satellite in this Earth observation program. This sensor, called a "thematic mapper (TM)" will record Earth surface radiation in seven bands. Spatial resolution will be improved to 30 meters, about two and one-half times better than previous Landsats. It is planned that the 4-band MSS will be included as part of the Landsat D payload.

The **return beam vidicon (RBV)** camera system for Landsats 1 and 2 consists of three high-resolution cameras which operate simultaneously and are aligned to record the same ground scene. Each camera has a different band within the spectral region from 0.48-0.83 micrometers. The RBV image covers an area of 185 x 185 km (115 miles) and is derived from only *reflected* solar radiation which impinges on the photosensitive tube. After the cameras are shuttered, the stored image on the

3 RBV Camera System, Landsats 1 and 2



2 RBV Camera System, Landsat 3

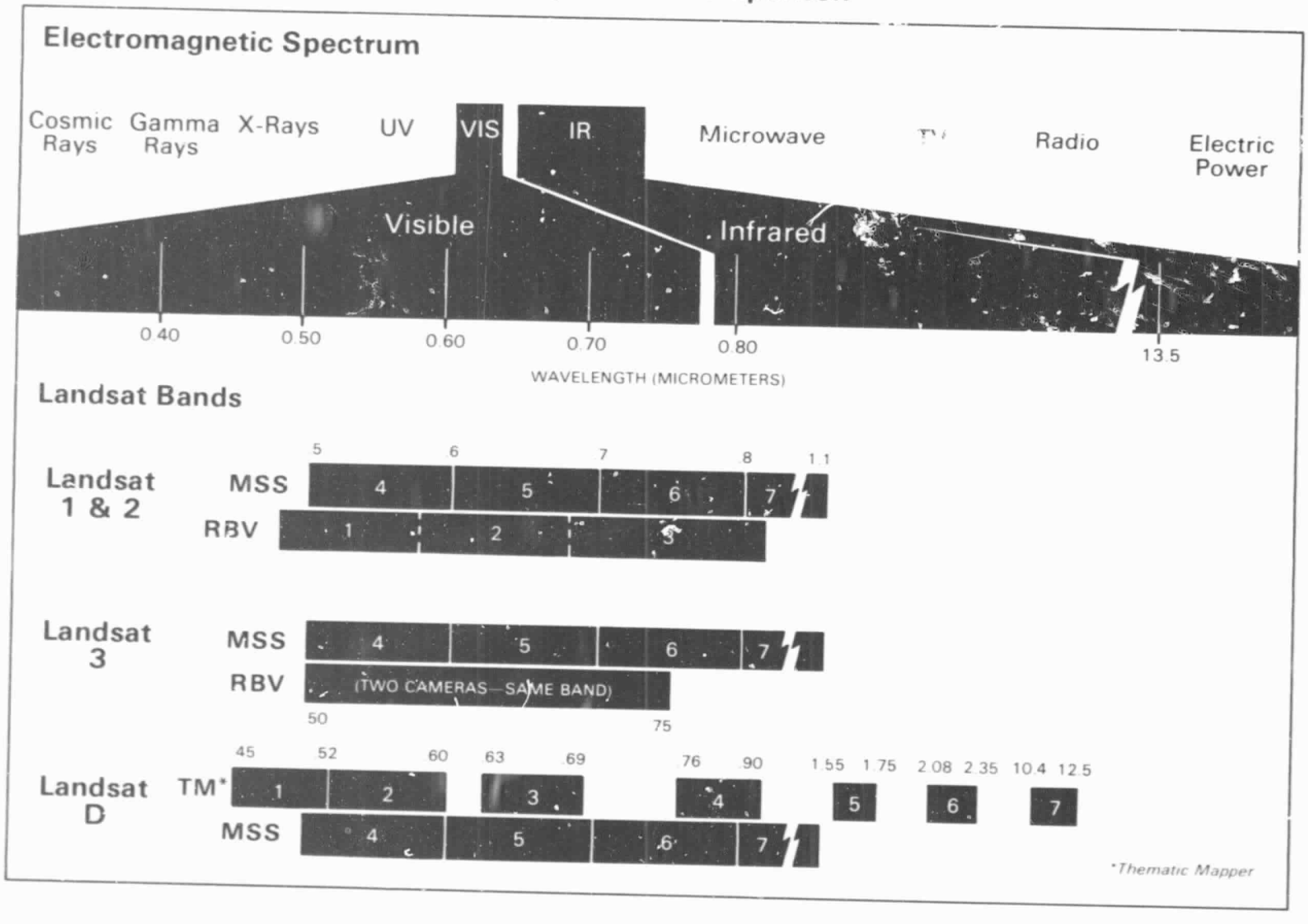


tube is scanned internally by an electron beam to produce a video signal output.

The RBV system of Landsat 3 is considerably different and contains just two cameras with improved ground resolution (40 m). Each of these two RBV sensors covers a 98 km (61 miles) square area and can be operated independently for either single frame or continuous coverage. When the two imaged areas are side by side and slightly overlapped, their total swath width is approximately 183 km (114 miles). Two consecutive pairs of RBV images, four frames, roughly match one MSS scene.

The MSS and RBV systems both view the Earth directly from beneath the spacecraft. The MSS image covers an area of 34,225 square kilometers (13,225 square miles), whereas one RBV image on Landsat 3 covers only 9,604 square kilometers

Landsat Bands and Electromagnetic Spectrum Comparison



(3,721 square miles). Other parameters of these two sensor systems are summarized in the following table.

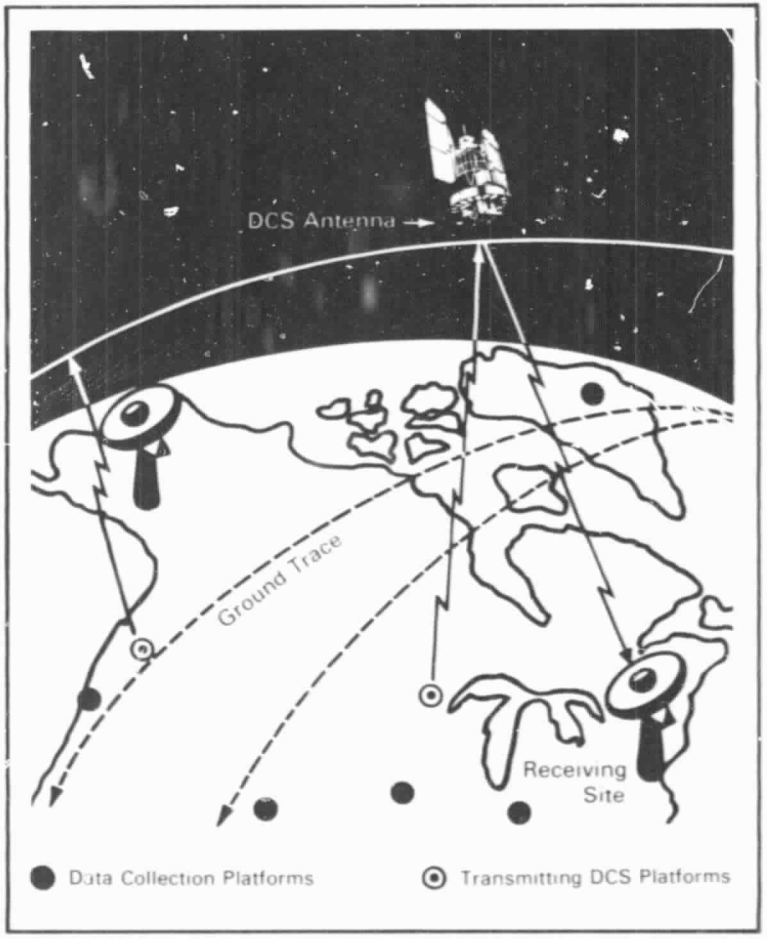
Characteristics of MSS and RBV

		Spectral Region	Ground Resolution	Ground Coverage
MSS Bands	4	.5-.6 μm	*80 m	185 x 185 km
	5	.6-.7	80	185 x 185
	6	.7-.8	80	185 x 185
	7	.8-1.1	80	185 x 185
RBV 3 Camera		.48-.58	80	185 x 185
		.58-.68	80	185 x 185
		.69-.83	80	185 x 185
RBV 2 Camera Landsat 3 only		.50-.75	40	98 x 98 km per camera

*Approximately 1.1 acres

The data collection system (DCS) is installed on all Landsat spacecraft; however, the DCS is currently activated only on Landsat 3. Ground data collection platforms throughout the United States receive data from as many as eight Earth-based sensors which sample environmental conditions such as temperature, stream flow, snow depth, and soil moisture. These data are relayed by Landsat from the transmitting collection platforms to receiving sites where decoding and formatting take place. Then the data are transmitted to the Goddard Space Flight Center, Greenbelt, Maryland, for final processing and delivery to the user. The DCS is designed to accept at least two platform transmissions per day (every 12 hours) and to make data available within 24 hours from the time Landsat relays the sensor measurements.

Data Collection System (DCS)



Ground Data Handling Segment

In the United States there are three Landsat data receiving stations:

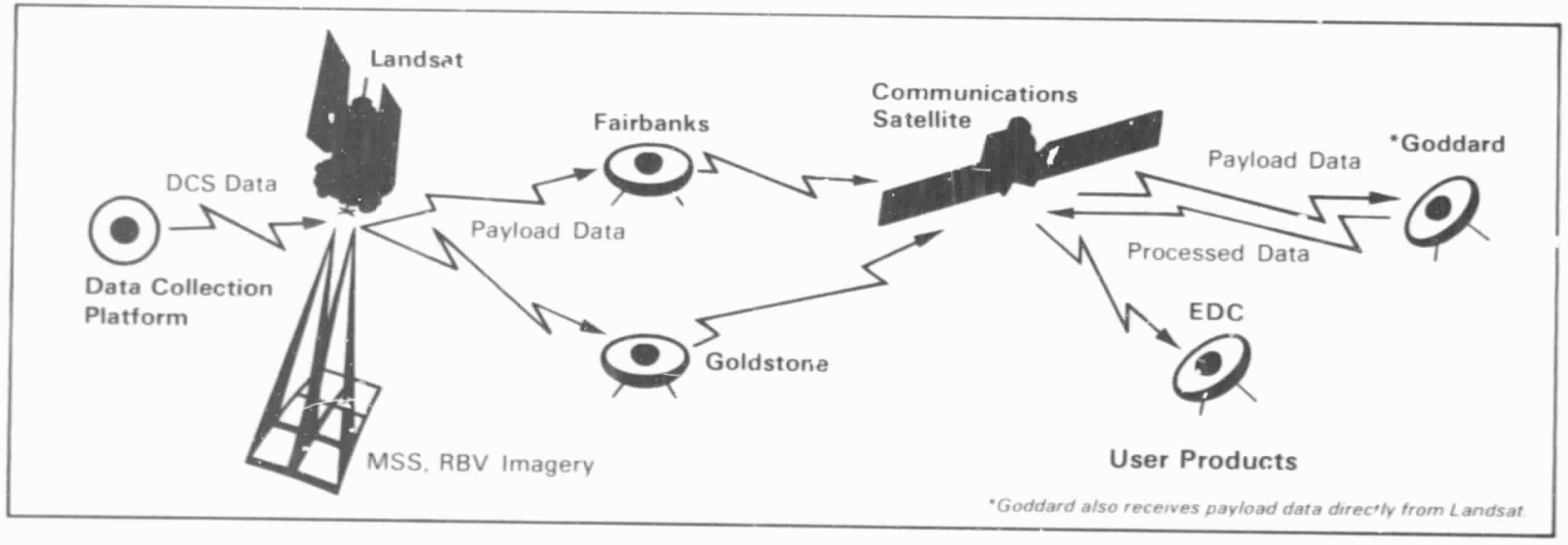
- Goddard Space Flight Center, Greenbelt, Maryland
- Goldstone Tracking Station, California
- Fairbanks Tracking Station, Alaska

In foreign countries active Landsat receiving stations are located in Brazil, Canada, Italy, Sweden, and Japan. As of July, 1979, additional stations are proposed for Argentina, Australia, and India.

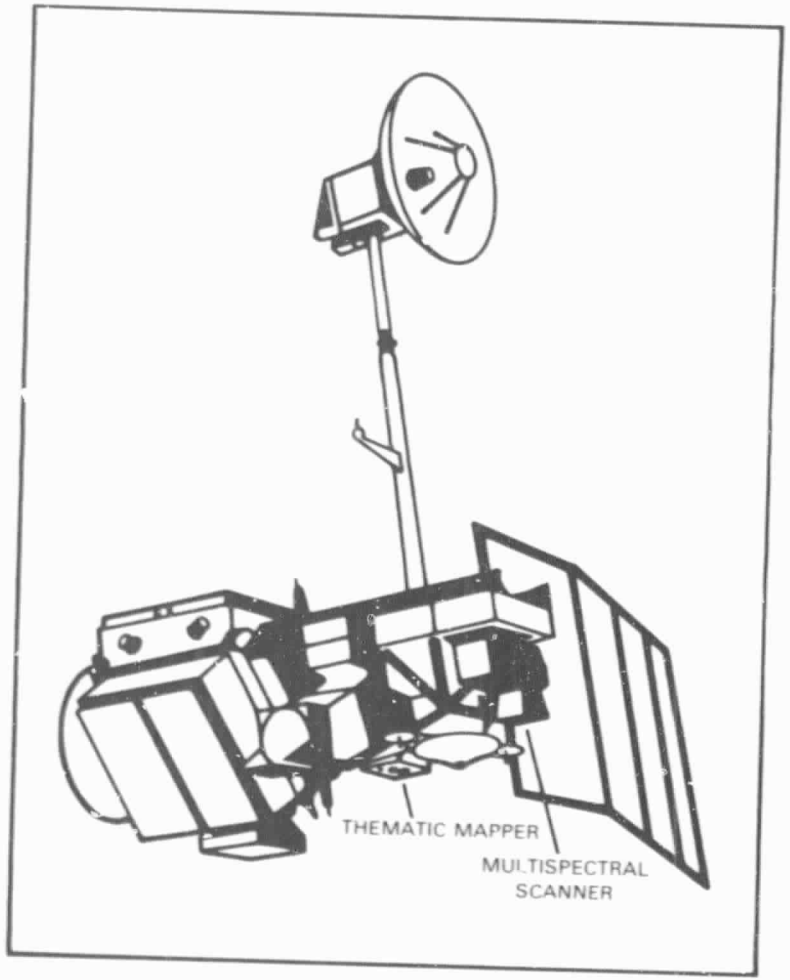
In the United States the three primary ground stations, mentioned above, accomplish all of the necessary communications with the Landsat spacecraft. These sites are equipped to handle MSS, RBV, and DCS data and perform all narrowband telemetry, tracking, and command functions. Other stations in NASA's Space Tracking and Data Network (STDN) provide backup for these latter functions.

The payload data (MSS, RBV imagery and DCS data) are received, demodulated, and recorded on magnetic tape at each ground station. These data are retransmitted by means of a communication satellite link from Goldstone and Fairbanks to the image data processing facility at Goddard. Currently, image data received at Goddard are radiometrically and geometrically corrected and then relayed to the EROS Data Center via a communications satellite. Finally, computer-compatible

Landsat Data Acquisition and Relay Sequence



Landsat D (Conceptual Design)



tapes (CCTs) and photographic products are produced by EDC for customer purchase and use.

Future Considerations

In the future, increased ground resolution and expanded spectral coverage will be provided by Landsat D. With these improvements, an additional cadre of users is expected to emerge. To further satisfy user needs for faster data delivery and greater flexibility of products, communications satellites are becoming an integral part of the total network for receiving and relaying Landsat data—from ground stations, to processing centers, to users. The Landsat D concept will feature a Tracking and Data Relay Satellite System (TDRSS), using DOMSAT links, which will improve data delivery time from spacecraft acquisition to availability for users.

Data Use and Users

Landsat Characteristics

An appreciation of Landsat's unique characteristics is essential to the useful application of the information it provides. There are advantages and limitations inherent in an Earth-orbiting observatory that is remotely sensing features on the Earth's surface.

The vast area covered in one Landsat scene—over 34,000 square kilometers—is an obvious characteristic that can provide an economic advantage in obtaining imagery of the Earth. Several thousand photographs by an aerial survey at a 1:20,000 scale would be required to cover the same ground area. Viewing the Earth from orbital altitude presents a perspective that can reveal geologic features, water drainage systems, urban growth trends, and other natural and cultural patterns.

The repetitive coverage of Landsat—approximately every nine days with two spacecraft—and its sun-synchronous orbit offer the opportunity for detection of changes and for updating natu-

ral resource information. Such repetitive and comprehensive data collection can be of significant value for planners and managers of natural resource and environmental programs.

Because Landsat data are provided in a digital form, the power and flexibility of computer technology can be brought to bear in the handling of vast data quantities, in the analysis of complex scientific problems, and in the production of specialized products. The latter includes tabulations, graphics, map overlays, statistical output, magnetic tape, film records, and other useful items.

The computer compatibility of Landsat data permits the merging of digital imagery with other numerical information such as geophysical, hydrologic, and socio-economic data sets. Landsat imagery can serve as base data for identifying larger scale (higher resolution) aerial survey needs or as a comprehensive format for overlaying topographic data and other information. The capability of Landsat data to complement or to be directly integrated with other data sources greatly enhances its value to users and, indeed, may be the most outstanding advantage offered by use of this space system.

Landsat spatial resolution and the extent of spectral coverage will be improved with the advent of Landsat D and its Thematic Mapper. The current use of communication satellite links to relay payload data from ground stations to processing facilities is improving product delivery times significantly. This communications approach will be further advanced in the Landsat D era.

The capability of Landsat to provide several spectral signatures of ground features is a valuable factor in the effective use of its imagery. Radiance received by individual detectors is converted into digital values within each band. The received signals, of varying strength, are digitized into 64 values (256 values for the Landsat Thematic Mapper).

These radiance values or levels, can be represented as color hues or gray tones in display devices or in photographic products. However, only portions of the total energy reflected from the Earth can be captured in Landsat's finite number of spectral bands, each of which presents a unique aspect of the same ground scene. Moreover, certain objects in a scene may yield more information about themselves in one spectral band than in another. The table below presents a summary of the most prevalent ground features observable on each of the four MSS bands. Because the spectral response of specific ground features is influenced by many variables, this table is very generalized.

MSS Spectral Bands Information Content (Generalized)

Band 4 - Sediment-laden water, shallow water, shallow water features such as shoals and reefs.

Band 5 - Cultural features such as urban areas and transportation networks; best band for general purpose analysis.

Band 6 - Vegetation, landforms, boundaries between land and water.

Band 7 - Atmospheric haze penetration, vegetation, landforms, boundaries between land and water.

Landsat Applications

Landsat data can be used in single band analyses for special features, or data from several bands can be combined and presented as a *color composite* image which is produced by assigning characteristic colors to individual bands. Typically, blue is assigned to band 4, green to band 5, and red to band 7. The resulting picture, approximating a color-infrared photograph, shows vegetation as red, clear water as dark blue, silty or polluted water as light blue, and bare fields, road networks, and urban areas as various shades of white, gray, and light blue.

Another typical application of Landsat imagery is based upon the identification of certain types of features from their unique spectral intensities. By discriminating natural and cultural features according to the intensity levels they generate within the various bands for a given scene, categories or classes of features can be established. These categories represent various types of land use or ground cover and can be made clearly distinguishable on a photograph by assignment of arbitrary colors to each class. The resulting product is called a land cover or land use map. See the illustration on the next page.

Usefulness of land cover classification maps is proportional to the accuracy and completeness of efforts in creating them. The identification and interpretation of features in a scene is a human function which can be directly aided by means of other information sources such as existing maps, aerial photography, and personal knowledge. Because it is not practical for a person to examine every picture element in a scene, the usual procedure is to first establish classifications based upon a minimum of positively known or determinable features. Then the computer is used to sort and classify all other picture elements accordingly.

It is important to note that color composite images and land classification maps are useful but only singular representations of digital data. It is perhaps more significant that these data are storable, transferable, and available for further use in analytical pursuits such as in merging of data sets, enhancement of imagery products, and inputting to mathematical models.

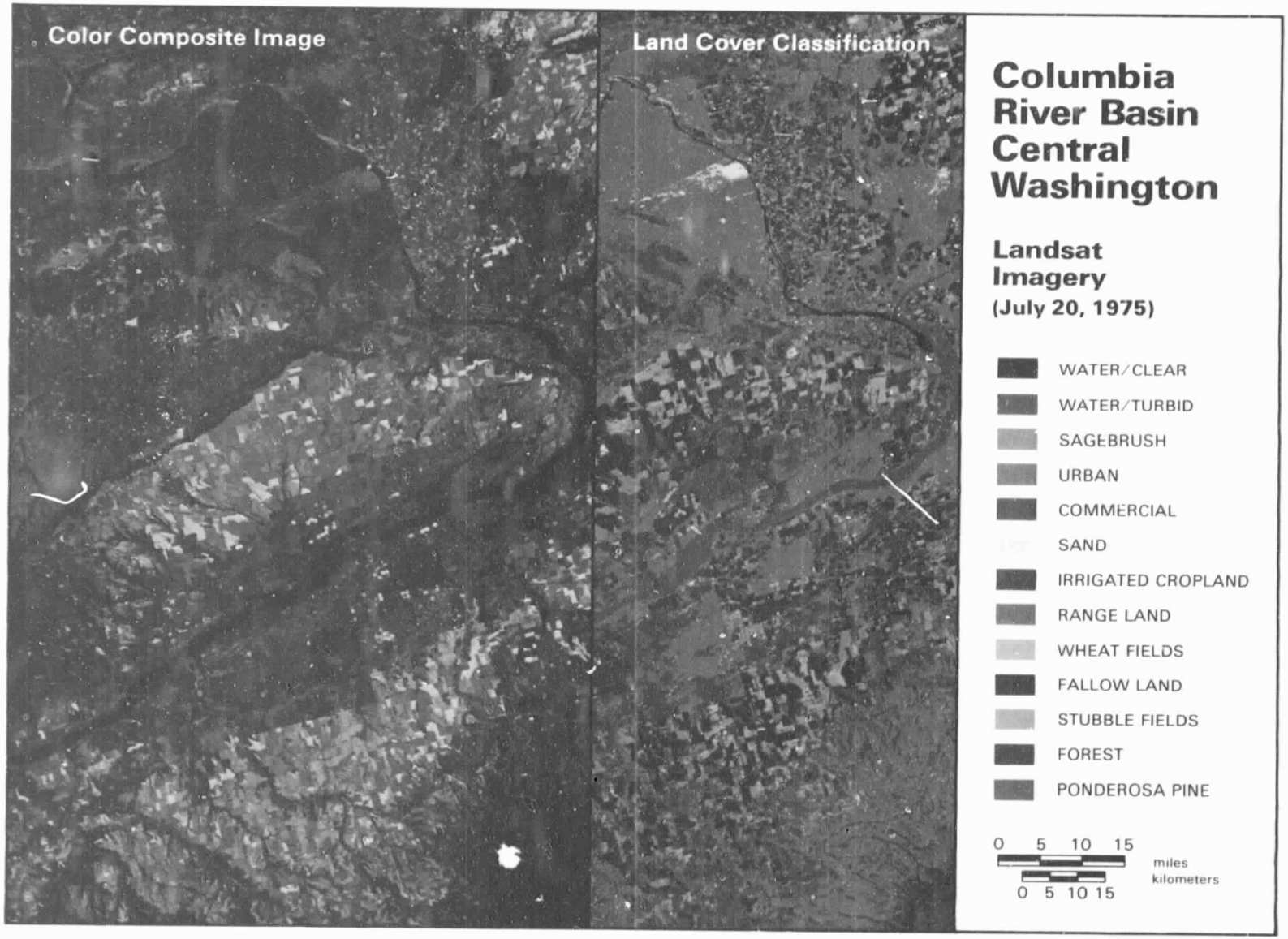
Landsat is used in many other applications, particularly those focused on the management and study of natural resources and the environment. Landsat can be more effective in combination with other data collection techniques than when used alone. However, there are situations where Landsat is the only available data source. Applications of Landsat data being developed to assist in various Earth resource disciplines are listed in a table on page 14.

Users of Landsat Data

In general, "users" are defined to be those individuals who have responsibilities and/or interests in processing, analyzing, or applying Landsat data or derived information. The user community is potentially very large and encompasses technicians, scientists, managers, and administrators in many sectors of our population. Within the United States most users can be categorized into four groups: industry, federal, state/regional, and academic.

Industry Users

Industrial and commercial firms have been prominent Landsat data user groups since the beginning of the Earth Resources Satellite program. Within the industrial group there are two major types of activities revolving about Landsat data use and products. First is the direct application of Landsat data to locate and monitor natural resources of commercial value such as minerals, fossil fuels, crops, timber, and water. Additionally, there are uses related to power plant sitings, land use/cover inventories, and construction monitoring. Those firms engaged



ORIGINAL PAGE
COLOR PHOTOGRAPH

Applications of Landsat Data Under Development

Agriculture, Forestry, and Range Resources	Cartography and Land Use/Cover	Geology	Water Resources	Oceanography and Marine Resources	Environment
Discrimination of vegetative types: Crop types Timber types Range vegetation	**Classification of land uses/cover**	**Identification of rock types**	**Determination of water boundaries and surface water area and volume**	**Determination of turbidity patterns and circulation**	**Monitoring surface mining and reclamation**
Measurement of crop acreage by species	**Mapping and map updating**	**Mapping of major geologic units**	**Mapping of floods and flood plains**	**Mapping shoreline changes**	**Mapping and monitoring of water pollution**
Measurement of timber acreage and volume by species	**Categorization of land capability**	**Revising geologic maps**	**Determination of areal extent of snow and snow boundaries**	**Mapping of shoals and shallow areas**	**Determination of effects of natural disasters**
Determination of range readiness and biomass	**Separation of urban and rural categories**	**Delineation of unconsolidated rock and soils**	**Measurement of glacial features**	**Mapping of ice for shipping**	**Monitoring environmental effects of man's activities (lake eutrophication, defoliation, etc.)**
Determination of vegetation stress	**Preparation of regional plans**	**Mapping igneous intrusions**	**Measurement of sediment and turbidity patterns**	**Study of eddies and waves**	
Determination of soil associations	**Mapping of transportation networks**	**Mapping recent volcanic surface deposits**	**Determination of water depth**		
Assessment of grass and forest fire damage	**Mapping of land-water boundaries**	**Mapping landforms**	**Delineation of irrigated fields**		
	Mapping of wetlands	**Search for surface guides to mineralization**	**Inventory of lakes and water impoundments**		
		Determination of regional structures			
		Mapping lineaments (fractures)			

in oil and mineral exploration businesses are the dominant users in the direct application of Landsat data.

The other major commercial activity is the selling of hardware, software, and analytical services related to Landsat. Industries engaged in this business are predominantly represented by aerospace and computer companies who have been traditionally active in offering remote sensing or digital data processing products and services. The products and services of these firms, related to Landsat applications, address a wide range of activities such as: land use/cover mapping, exploration assessment, agricultural and forest inventorying, water resources and environment monitoring, and image data analysis development.

Federal Government Users

Federal agencies have been one of the largest Landsat user groups since the beginning of the program. Nearly 30 major federal organizations are identified as Landsat data users, including components of the Departments of Agriculture, Commerce, Defense, Energy, Interior, State, and Transportation; also, the Environmental Protection Agency, the Tennessee Valley Authority, and the National Aeronautics and Space Administration.

The use of Landsat data by federal agencies can be categorized in four levels:

1. **Planned or Potential Use**

   Application possibilities are recognized and desire expressed to evaluate and use the data.

2. **Experimental Use**

   Application possibilities are evaluated in technical, economic, and institutional aspects.

3. **Quasi-Operational and Demonstration Use**

   Methodologies for routine use of Landsat data are developed and demonstrated.

4. **Routine Operational Use**

   Landsat data are applied in normal operations and associated costs undertaken solely by the using organization.

The majority of federal agencies employing Landsat data are involved at the second and third levels of activity. The Geological Survey is one of these federal user organizations that is incorporating use of Landsat data on a routine operational basis. Other organizations, such as the U.S. Army Corps of Engineers, have historically employed remote sensing in their activities and are gradually approaching the stage of operational usage of Landsat data.
Earth observation by satellite and allied remote sensing applications, in research and development by federal agencies, are summarized below by disciplines:

- **Agriculture**

  Forest, crop and soil classification, inventories and mapping; crop condition monitoring and yield prediction; disease detection; forest, range and grassland management.

- **Geology**

  Mineral and fossil fuel exploration, geological mapping.

- **Hydrology**

  Water quality, reservoir mapping and monitoring, snowfall and runoff estimates, flood damage assessments, irrigation management.

- **Ecology and Environment**

  Wildlife habitat, surface mining monitoring, coastal zone and critical area management.

- **Cartographic and Land Use/Cover**

  Data base formulation, broad category land use classification, environmental planning, topographic and thematic mapping.

- **Oceanography**

  Iceberg and sea ice monitoring, ocean resources.

State, Regional, and Local Government Users

State, regional, and local government agencies have increasing responsibilities and authority for planning and managing natural resources because of national interest and specific legislation in these vital functions. Resource data must be collected frequently to comply with state laws such as California's Coastal Zone Conservation Act and with federal requirements such as those under Section 208 of the Water Pollution Control Act and Reclamation Act of 1977. As a result, this user group is actively seeking dependable and responsive sources of information to supplement or replace conventional data collection techniques.

An operational Landsat system can potentially provide much of the needed data collection. This satellite technology and resulting data products have been evaluated by at least thirty-five states for operational applications. As of 1978, seven states had independent, on-going operational Landsat analysis and application capabilities. Several of these states are using Landsat data extensively in natural resource planning and management. Major application areas of Landsat data for this user group are the following:

- Land cover inventory
- Water quality assessment
- Wildlife habitat inventory
- Geologic lineament mapping
- Surface water inventory
- Flood control, mapping, and damage assessment
- Crop inventory
- Geologic mapping
- Forest inventory

Academic Users

Academic users of Landsat data are highly diversified and generally are aligned with an Earth science or resource discipline such as forestry, geology, ecology, agronomy, oceanography, demography, geodesy, etc. A large segment of this user community is involved with computer processing for image data handling and interpretation. Academic users have been instrumental in developing Landsat analysis techniques, providing technical leadership, and rendering valuable insight for other user groups in the application of satellite imagery. These efforts have been primarily research oriented, but Landsat data have also been employed for educational purposes.

The faculty members, researchers, and students at academic centers offer specialized expertise and uniquely designed equipment that frequently have a catalytic effect in promoting new remote sensing techniques and uses. Many of these are the outgrowth of long-standing remote sensing interests in the processing and utility of data collected from space. Other studies are related to the direct application of Landsat data to discipline and functional areas. The following table of study topics by members of the academic community illustrates their wide range of research interests and, as one would expect, overlaps with the applicational uses supported by the other major user groups.

Products and Costs

Landsat Data Products

The Landsat user can obtain products ranging from routine hard copy imagery to highly specialized data enhancements. In general, the EROS Data Center (EDC) supplies the standard products most frequently used in typical applications whereas commercial vendors offer more specialized analyses and custom-made products.

The standard Landsat data products offered by EDC include black and white imagery, color composites, and computer compatible tapes (CCTs). The price list as of January, 1979, is shown on the following page.

Procedures and forms for obtaining products from EDC are well documented in general information packages that can be provided on a phone call request (User Services Section, (605) 594-6511). Two microfiche systems are also available for the determination of Landsat coverage and related reference information. The microIMAGE system provides a browsing capability for users to study a representative scene before ordering full-size photographs or CCTs. The microCATALOG system is a cumulative listing of several thousand computer printouts which describe existing Landsat coverage of world-wide geographic locations.

Landsat Data Applications Being Investigated by Academic Users

- Agricultural inventories
- Air pollution studies
- Archeological interpretation
- Coastal studies
- Coral reef monitoring
- Crop yield
- Education of users
- Environmental analysis
- Erosion studies
- Estuarine management
- Flood hazards
- Flooding assessment
- Forest inventories
- Geography
- Geologic studies and mapping
- Geomorphology
- Geothermal studies
- Ground-water mapping
- Hydrological studies
- Ice jam flooding
- Insect damage to crops
- Interpretation techniques development
- Irrigated land studies
- Lake water quality monitoring
- Land cover and land use mapping
- Landslide mapping
- Meteorology
- Mineral resource location
- Modeling techniques
- Oceanography (physical)
- Rangeland inventories
- Recreational area mapping
- Shoreline form analysis
- Snow avalanche mapping
- Snow cover mapping
- Soil moisture studies
- Soil surveys
- Strip mine mapping
- Strip mine reclamation
- Teaching methodology
- Urban and regional planning
- Vulcanological studies
- Water circulation studies
- Water resources
- Water use by agricultural crops
- Wetland ecology and mapping
- Wildlife habitat and studies

Standard Landsat Data Products

PHOTOGRAPHIC *Prices subject to change*

Nominal Image Size	Product Material	BLACK & WHITE Unit Price	BLACK & WHITE Product Code	COLOR Unit Price	COLOR Product Code
55.8mm (2.2 in.)	Film Positive	$8.00	11	NA	NA
55.8mm (2.2 in.)	Film Negative	10.00	01	NA	NA
18.5cm (7.3 in.)	Paper	8.00	23	$12.00	63
18.5cm (7.3 in.)	Film Positive	10.00	13	15.00	53
18.5cm (7.3 in.)	Film Negative	10.00	03	NA	NA
37.1cm (14.6 in.)	Paper	12.00	24	25.00	64
74.2cm (29.2 in.)	Paper	20.00	26	50.00	66

Color Composite Generation	$50.00	59

NOTE: 1) Portrayed in false color (infrared) and not true color.
2) Cost of product from this composite must be added to total costs.

CCT

Tracks	BPI	Format	MSS ALL BANDS AVAILABLE Product Code	MSS ALL BANDS AVAILABLE Price	RBV SINGLE SUBSCENE Product Code	RBV SINGLE SUBSCENE Price	SET OF FOUR RBV SUBSCENES Product Code	SET OF FOUR RBV SUBSCENES Price
9	800	Tape Set	183-B	$200.00	183-C	$200.00	183-D	$400.00
9	1600	Tape Set	184-B	200.00	184-C	200.00	184-D	400.00

Both of these microfiche indexes are keyed to the Landsat Worldwide Reference System (WRS) which is a global network of paths and rows by which all Landsat scenes can be geographically located. The WRS network is printed on a map base and shows the nominal locations of scene centers which correspond to the intersection of the satellite north-south ground track ("path") and designated east-west lines ("rows"). By using a coverage template, provided with each WRS map, one can find an area of interest, within a scene and identify that scene by the path/row coordinates.

EDC also provides a service for determining the availability of imagery covering selected geographic points or areas of interest. The user can specify the preferred type of coverage (Landsat, Skylab, NASA aircraft), time of year, image quality, and acceptable cloud cover. Results of the inquiry will be returned on a computer listing along with a decoding sheet, from which imagery can be selected and ordered.

Landsat products and services can be procured from *commercial sources* but generally require a computer compatible tape from EDC if computer processing is involved. The tape can be obtained by either the user or the commercial firm engaged to perform a given task. It is beneficial and cost-saving for the user to clearly identify the study area and features of interest, and to provide the contractor with maps, annotated aerial photographs, and other supporting information.

There are three broad types of Landsat data products/services which commercial sources provide: image enhancements, land use/cover classifications, and end product generation. The latter service is available for those users who have basic computer processing hardware but lack peripheral hardware used to produce products such as color composites and line printer graphics. A summary of these products/services and associated cost ranges are presented in the accompanying table.

Commercial Costs for Typical Landsat Computer-Processed Products

Enhancement (one scene)	$900-2500
Classifications (land use/cover)	
Within one scene	$2000-5000
Multiple scenes (mosaicking)	$6000-11000 per pair
Peripheral Services (one scene or less)	
Single band image print	$100-200
Color composite print (three bands)	$200-500
Land use/cover map	$250-600
Electrostatic printer output	$50-100

A decision to contract for commercial services is usually based on the fact that EDC does not provide the desired Landsat data product or that specialized processing and analysis are needed. Specific feature enhancement, special band color assignment, integration with other data sets, unusual product size or scale, and addition of special annotations are some examples of unique customer-oriented requirements.

Supplemental Data Products

Landsat data applications frequently involve the use of existing and/or new aerial photography. The availability of existing aerial images may be further pursued through the National Cartographic Information Center (NCIC) which maintains a computerized data bank describing the scale and format of all federally-owned high and low level aerial imagery. The predominant sources of this photography are the Department of Agriculture, the Geological Survey, NASA, the National Ocean Survey, the Corps of Engineers, and the Tennessee Valley Authority. Duplications of aerial photographs from federal sources usually are based on a 9-inch square format. Typical NCIC prices are:

Black and white imagery	Color
film positive - $5	film positive - $15
film negative - $6	paper print - $7
paper print - $3	

The imagery can also be printed on photographic paper at specified magnifications for an additional cost. (Addresses for the referenced federal sources are provided in the back pages of this publication.) Commercial firms engaged in aerial surveys also have considerable holdings of imagery; the interested user can identify these sources in local telephone directories.

Types and Sources of Federal Maps

Type	Publisher	Type	Publisher
Electric facilities	FPC	Mineral resources maps and charts	USGS
Geologic quadrangle maps	USGS	National forests:	
Geologic investigations maps	USGS	Forest regions	FS
Geologic map of North America	USGS	National forest index	FS
Geophysical investigations maps	USGS	National parks:	
Highways:		Topographic maps	USGS
United States	FHA	National parks system	NPS
State and county	SHD	Natural gas pipelines	FPC
Hydrographic information:		Polar maps:	
Nautical charts of U.S. coastal waters	NOS	Antarctic	NOS, HC, USGS
Great Lakes and connecting waters	NOS, Lake Survey Center	Arctic	NOS, TC
		Railroad map, United States	TC
River charts:		Soil survey maps	SCS
Cumberland River	COE, Nashville	Topographic map series, United States	USGS
Middle and Upper Mississippi River and Illinois Waterway to Lake Michigan	COE, Chicago	Indexes to published topographic maps, each state and U.S. territories	USGS
Lower Mississippi River	COE, Vicksburg	Status indexes to aerial mosaics/ photography and topographic mapping, U.S.A.	USGS
Missouri River	COE, Omaha		
Ohio River	COE, Cincinnati		
Tennessee River	TVA, Chattanooga	Public land maps	BLM
Foreign waters	DMA	United States base maps	USGS, NOS
Hydrologic investigations atlases	USGS	Water Resources Development map	USGS
Indian reservations	BIA	World maps	HC, TC, NOS
Land use and land cover maps	USGS		

KEY

BIA - Bureau of Indian Affairs	FPC - Federal Power Commission	SCS - Soil Conservation Service
BLM - Bureau of Land Management	FS - Forest Service	SHD - State Highway Departments
COE - Corps of Engineers	HC - Hydrographic Center, DMA	TC - Topographic Center, DMA
DMA - Defense Mapping Agency	NOS - National Ocean Survey	TVA - Tennessee Valley Authority
FHA - Federal Highway Administration	NPS - National Park Service	USGS - U.S. Geological Survey

The NCIC is also a primary source for maps covering the United States. The Geological Survey topographic maps are the most frequently used ones in combination with Landsat data analysis; for example, a typical graphic is a 7-1/2 minute quadrangle map, 1:24,000 scale, which presents features such as roads, buildings, streams, dams, mineral deposits, elevations, boundaries, fences, vegetation, and power lines. A standard map of this type costs approximately $1.25. For several dollars a customized map product can be made at specified scales from available cartographic materials. Types (and publishers) of federal maps which may be useful in Landsat data analyses are summarized in the accompanying table. Additional information on specific maps can be obtained from the NCIC regional offices.

Additional information about features of interest on the Earth's surface, that helps to improve the quality and accuracy of interpreting remote sensing data, can be provided through ground control. This information is particularly useful in preparing land use classification maps with Landsat imagery. The needed information can be obtained from sources such as personal knowledge, reference documents, and on-site observations. The use of field survey parties to obtain ground control data can cost from $50 to $100 per day for each person. Therefore, it is advisable to minimize or avoid expensive field survey efforts by first identifying and using all existing collateral information that is available for the study area.

User Assistance Sources

In response to its broad charter "to provide for the widest practicable and appropriate dissemination of information concerning its activities and results thereof," NASA has given much specific attention to remote sensing technology transfer as it relates to development of satellite data users, in general, and Landsat applications, in particular. At the same time the U.S. Geological Survey, Department of Interior, also has provided extensive user training and assistance through the EROS Data Center and the National Cartographic Information Center.

The establishment of the Regional Remote Sensing Application Program by NASA in 1977 was primarily intended to assist in the evaluation of Landsat technology by state governments and regional groups for their potential application areas, but it is available to all interested users. Although the program draws upon the expertise and resources of all NASA centers, three organizations have prime responsibility in assigned geographic areas of the United States:

- The Eastern Regional Remote Sensing Applications Center (ERRSAC), Goddard Space Flight Center, Greenbelt, Maryland, serves the northeastern and north-central states plus Puerto Rico and the Virgin Islands.

- The Western Regional Applications Program (WRAP), Ames Research Center, Moffett Field, California, serves the western states including Alaska and Hawaii.

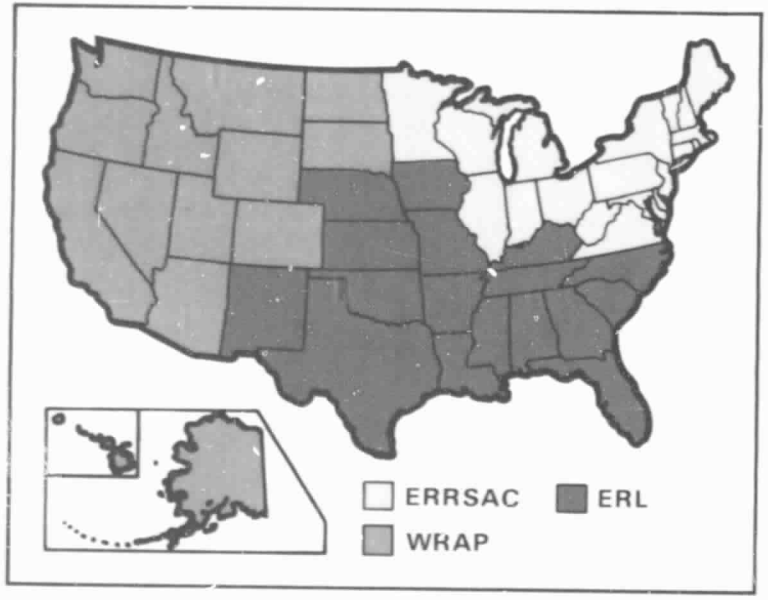
- The Earth Resources Laboratory (ERL) of the National Space Technology Laboratories, Mississippi, serves the south-eastern and south-central states.

The functions of these organizations can be outlined as follows:

- familiarize prospective Landsat data users with the experience of current users and with potential applications of remote sensing by means of briefings, workshops, and special publications;

- provide hands-on training and orientation programs compatible with user needs in such areas as computer image analysis, data management, and user-specific applications as preparation for participation in demonstration projects;

Regional Centers, Areas of Responsibility



- conduct cooperative practical demonstrations with user agencies to determine if and how remote sensing technology can be applied to their informational and decision-making needs; and

- provide follow-on technical assistance to users who intend to develop an independent capability to use Landsat data and to help them incorporate the technology into their operational system.

In addition to NASA's Regional Remote Sensing Applications Program, other sources of user services are available. The EROS Data Center (EDC) also trains and assists users in the application of remotely sensed data. Periodically, workshops of varying length are offered at EDC or in the field and stress the use of Landsat data for a particular application. EDC also provides day-to-day assistance and demonstration projects in cooperation with users. There are three other Application Assistance Facilities operated by EDC in Alaska, Mississippi, and the Canal Zone.

The National Cartographic Information Center (NCIC), another office within the U.S. Geological Survey, maintains information bases on the cartographic data held by federal, state, and private agencies and has direct links to the EDC research and ordering system. NCIC is headquartered in Reston, Virginia, with regional offices at each USGS Mapping Center in Virginia, Missouri, Colorado, and California. Additionally, NCIC has established affiliated offices in several states. These offices have subsets of the various information bases and some maintain computer links with EDC.

Regional cartographic data including space imagery, aerial photography, and maps and charts are also available from sources within various agencies of the individual state governments.

The National Conference of State Legislatures (NCSL) is an organization designed to help state lawmakers and their staffs meet the challenges of today's complex federal system. Because of the promise of Landsat-derived data in the management of land, the environment, and natural resources, NCSL has established a Task Force and a Natural Resources Information Systems Project which continually monitors the rapidly developing Landsat technology. NCSL communicates significant information of practical utility to the states and provides direct assistance such as:

- informational materials for legislators describing the uses and limitations of satellite technology in decision making;

- seminars and workshops for interested legislators and their staffs to obtain more detailed information on satellite technology, its relative benefits, and costs; and

- continual updates for legislators on the rapidly-changing nature of satellite technology as an aid to the growing needs of energy, air, water, and land management.

A Legislator's Guide to Landsat is an NCSL publication which is representative of the informational materials generated by this organization.

The National Governors' Association (NGA) is another organization oriented to the problems of state and local governments in obtaining and making use of natural resources data. NGA's Council of State Planning Agencies (CSPA), in cooperation with NASA and interested state agencies, is building on lessons learned from Landsat technology to improve communication networks and opportunities for states to apply new technologies appropriate to their needs. Toward this end, the Earth Resources Data Project has been established and includes the following elements:

- an advisory panel, The Earth Resources Data Council, addressing state problems of natural resource needs;
- research studies to provide useful information to state officials and decision-makers on topics such as present use of Landsat data in natural resource programs;
- an information exchange system through media such as NGA newsletters, and policy users brochures; and
- forums, workshops, or other appropriate means to consolidate state views on various data issues and to provide technical assistance to states.

Note: Points of contact and organizational addresses for components of EDC, NCIC, state agencies, and the NCSL are presented in the back pages of this document. The reader is referred to Module U-5, "Sources for Landsat Assistance and Services," for commercial and academic organizations that provide services, products, and training.

Selected References

Landsat technology and data applications have been extensively discussed and documented in various briefings, guides, reports, monographs, books, and other publications. The most important single reference document for system information is the *Landsat Data Users Handbook*, 1979 Revised Edition, prepared by USGS in cooperation with NASA. This handbook, which can be purchased from the EROS Data Center, is described below along with other selected references and sources of pertinent Landsat-related information.

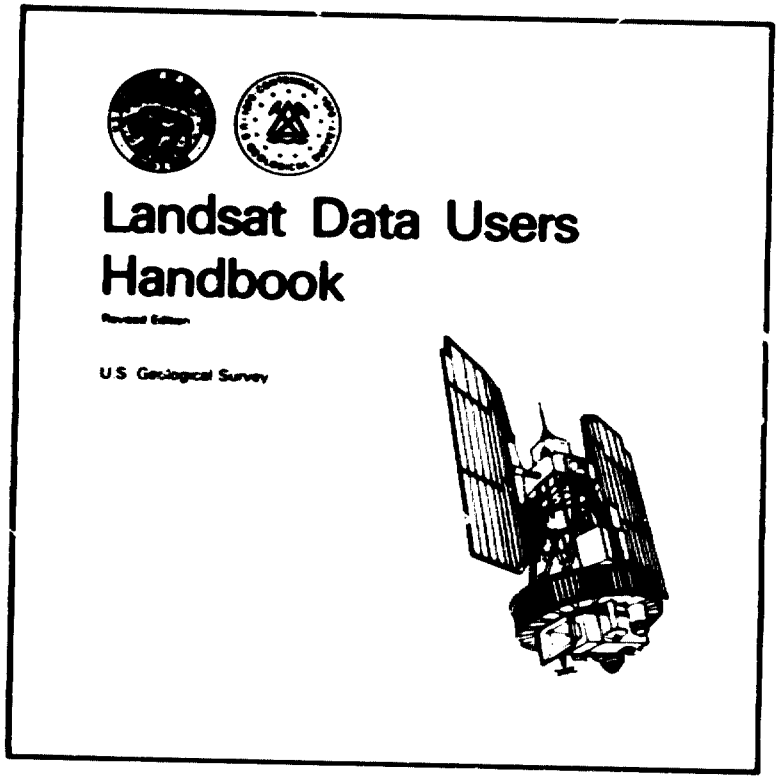
Handbooks, Guides, Texts

Landsat Data Users Handbook, 1979 Revised Edition, U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota 57198.

The intent of this looseleaf handbook is to satisfy Landsat user needs for information about the Landsat system and data products. The main body of the handbook provides a detailed description of the Landsat system, observatories and payload, orbits, and operational aspects. Data handling and processing procedures including the current digital processing practices at both NASA and EDC are described in detail. Eight appendices provide additional information including data ordering procedures and forms.

ERTS-1: A New Window on our Planet, edited by Richard S. Williams and William D. Carter, 1976. U.S. Geological Survey Professional Paper 929 (For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Stock No. 024-001-02757-7), 362 pages.

This book reviews in detail a wide range of examples and case histories that demonstrate the practical applications of Landsat



to inventorying resources, monitoring environmental conditions, and facilitating decision making in several activities that come under the auspices of the Department of the Interior. Supplemented by over 250 figures (many Landsat images in color), this book documents representative applications of Landsat data including cartography, geologic mapping, mineral resource evaluation, water inventorying, coastal and wetlands management, and land use assessment.

A Legislator's Guide to Landsat, National Conference of State Legislatures, 1405 Curtis Street, Denver, Colorado 80212.

In 1976 the National Conference of State Legislatures established a task force to review the feasibility of using Landsat technology in state and local government. As a result, this organization published a guide which addresses the importance of Landsat to state government, and provides a general overview of the Landsat system, data applications, institutional approaches, and Landsat information sources.

Manual of Remote Sensing, Robert G. Reeves, Editor-in-Chief, American Society of Photogrammetry, 105 North Virginia Avenue, Falls Church, Virginia, 22046 1976.

Volume 1 of this two-volume reference book provides detailed technical explanations of the theory, principles, and techniques of photogrammetric and remote sensing systems. Volume 2 summarizes photographic interpretation and applications for areas of interest including cartography, terrain and minerals, forest lands, range resources, water resources, marine environment, weather and climate, assessment of crops and soils, urban environment, and engineering applications. This reference book includes twenty-six chapters with contributions from over 200 authors; it is fully illustrated and completely indexed.

Mission to Earth: Landsat Views the World, N. M. Short, P. D. Lowman, Jr., S. C. Freden, and W. H. Finch, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, 1976, 459 pages; (Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Stock No. 033-000-0069-4).

This is a compendium of approximately 400 Landsat pictures (many are color lithographs) which display Landsat-1 scenes around the world (40 percent of which are of the United States). Accompanying each image is a caption which notes geographic points of interest, geologic features, land use, and land cover. A comprehensive explanation of the Landsat spacecraft and its data-gathering systems and a review of Landsat accomplishments and applications are contained in the introduction and appendices.

Practical Applications of Space Systems, Space Applications Board, National Research Council of the National Academy of Sciences, 2101 Constitution Avenue NW, Washington, D.C. 20418, 1975, 67 pages.

This report of the findings of several user-oriented panels provides a summary of space application programs and identifies needs that might be met by data, information, or services derived from Earth-orbiting satellites. Over seventy senior and experienced user specialists from government, industrial, and academic communities were grouped in the following panels: Weather and Climate; Communications; Land Use Planning; Agriculture, Forest and Ranges; Inland Water Resources; Extractable Resources; Environmental Quality; Marine and Maritime Uses; Materials Processing in Space; Information Services and Information Processing; Space Transportation; Costs and Benefits; Institutional Arrangements and Space Technology. Several of the application recommendations focus on the Landsat system. Supporting papers are also available for each of the panels.

Remote Sensing Principles and Interpretation, Floyd F. Sabins, W. H. Freeman and Company, 660 Market Street, San Francisco, California 94104, March 1978, 426 pages.

This remote sensing textbook summarizes the basic principles and skills required to interpret all forms of remote sensing imagery including aerial photography, manned satellite imagery, Landsat imagery, thermal infrared imagery, and radar scenes. Practical applications of remotely sensed data to geography, the environment, land use, oceanography, and geology are emphasized; a chapter on digital image processing relates computer techniques for restoration and enhancement of images and for information extraction. This book also contains an extensive glossary of remote sensing terms.

Remote Sensing of Environment, edited by Joseph Lintz and David Simonett, Addison-Wesley Publishing Company, Inc., Jacob Way, Reading, Massachusetts 01867, 1976.

This book includes descriptions of both discipline applications of remote sensing technologies and the principles of remote sensing science. Part I synopsizes the fundamentals of physics from which remote sensing technology draws; Part II characterizes various sensor systems; and Part III outlines a six-step systems approach to problem solving utilizing remotely sensed data. Included within the text are descriptions of the Landsat system and examples of Landsat data applications.

Journals and Newsletters

Periodicals most frequently containing Landsat information include the two major remote sensing journals and various remote sensing related newsletters, which are listed below. The newsletters listed generally have a more narrow informational and geographic focus applicable to the interests of the publishing organization. It is expected that other newsletters will appear as new user groups emerge.

Photogrammetric Engineering and Remote Sensing, Journal of the American Society of Photogrammetry, 105 North Virginia Avenue, Falls Church, Virginia 22046, (subscription rate is $30/year for nonmembers).

This monthly publication facilitates the exchange of ideas and the dissemination of knowledge and new information about the applications of photogrammetry and remote sensing. This publication also includes advertisements of commercial firms providing remote sensing services and equipment, book reviews, and future symposium notices; an index to articles published is provided once a year.

Remote Sensing of Environment, Elsevier North-Holland, Inc., 52 Vanderbilt Avenue, New York, New York 10017; (subscription rate is $22/year).

This quarterly international and interdisciplinary journal includes diverse articles on remote sensing theory, results of

scientific experiments, and designs/applications of remote sensing systems. Landsat related articles include research papers from several disciplines which discuss comprehensive state-of-the-art applications.

Newsletters

Landsat Data Users Notes, U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota 57198

Plain Brown Wrapper, Western Regional Applications Program, NASA Ames Research Center, Moffett Field, California 94035.

The RAP Sheet, NASA National Space Technologies Laboratories, Earth Resources Laboratory, NSTL Station, Mississippi 39529.

Reflections, Eastern Regional Remote Sensing Applications Center, NASA/GSFC Code 902.1, Greenbelt, Maryland 20771.

Remote Sensing, National Conference of State Legislatures, 1405 Curtis Street/23rd Floor, Denver, Colorado 80202.

Kansas Applied Remote Sensing Newsletter. The University of Kansas Center for Research, Inc., 2291 Irving Hill Drive, Campus West, Lawrence, Kansas 66045.

The Cornell Remote Sensing Newsletter, Cornell University, 464 Hollister Hall, Ithaca, New York 14853.

Pixel Facts, Pacific Northwest Land Resources Inventory Project, NASA Ames Research Center, M/S 240-4, Moffett Field, California 94035.

University of Arizona Remote Sensing Newsletter, Office of Arid Lands Studies, University of Arizona, Tucson, Arizona 85721.

Nebraska Remote Sensing Center News, Nebraska Remote Sensing Center, University of Nebraska, Lincoln, Nebraska 68588.

User Surveys

User surveys have been conducted in recent years to document the applications and effectiveness of Landsat data use in Earth resources applications. Two of these surveys are the following:

Survey of Users of Earth Resources Remote Sensing Data, NASA, Office of User Affairs and Applications, Washington, D.C. 20546, March 1976, 144 pages.

This NASA survey analyzes specific applications of space and high-altitude aircraft data by over 1,000 users in five categories (industry; federal government; state, regional, and local government; educational/academic; and foreign). The survey provides a profile of each user community including types of data used, discipline/applications of interest, funding sources, and specific Landsat data assessments and recommendations.

State and Local Government Perspectives on a Landsat Information System, prepared by the Natural Resource and Environment Task Force of the Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP), Office of Science and Technology Policy, Executive Office of the President, Washington, D.C. 20500, June 1978.

This report summarizes the results of a 1978 survey of state, regional, and local governmental agencies. The report includes the purposes, extent, and value of Landsat data used by state and local governments; the commitments which states have made to using Landsat data; the constraints which have prevented states from utilizing Landsat data more fully; recommendations as to how the Landsat system can be structured to be more useful to state and local governments; identification of

the types of assistance required by governmental agencies to achieve operational capabilities; and the identification of governmental roles and pricing policies for Landsat data.

Symposium Proceedings

In recent years, Landsat has been the focus of several papers and discussions at various conferences. Proceedings of the following representative symposia include relevant Landsat-related information. In addition, several universities and professional societies offer short courses and seminars in remote sensing and publish course materials and proceedings.

NASA Earth Resources Survey Symposium, Houston, Texas, June 1975, seven volumes (available from NTIS as NASA TM-58168).

This was the first comprehensive symposium on the practical application of Earth resources survey data and included the utilization and results of data from NASA programs involving Landsat, the Skylab Earth resources experiment package, aircraft, and other data acquisition programs. Volumes I-A, I-B, I-C, and I-D contain the technical papers presented during sessions on Agriculture-Environment, Geology-Information, Land Use-Marine, and Water applications, respectively. Volume II-A contains the opening day plenary session presentations on Coastal Zone Management, State and Local Users, and User Services. Volume III contains a summary of each session which provides an overview of the significant applications that have been developed, and the conclusions and needs identified during the individual sessions and workshops.

Proceedings of International Symposia on Remote Sensing of Environment, conducted by the Environmental Research Institute of Michigan (ERIM), in cooperation with the University of Michigan Extension Service, Post Office Box 8618, Ann Arbor, Michigan 46107.

Since 1962, twelve symposia have been held throughout the world. Among the 125 or more papers presented at the last three symposia, several have addressed Landsat technology specifically. Various sessions of these symposia have included reviews of national remote sensing programs; data collection, processing and interpretation technologies; and utilization of remote sensing technologies for various disciplinary applications including geology and mineral resources, vegetation and soil resources, hydrology and water resources, meteorology and climatology, land and cultural resources, and ocean and marine resources.

Machine Processing of Remotely Sensed Data Symposium Proceedings, Laboratory for Applications of Remote Sensing (LARS), Purdue University, West Lafayette, Indiana 47907 (available from IEEE Sales, 4205 Hoes Land, Piscataway, New Jersey 08854).

Since 1973 five symposia on the machine processing of remotely sensed data have been held at LARS. These symposia have focused on the application of remote sensor systems; and computerized data processing to Earth resources problems. Several papers have been presented which have highlighted general Landsat data applications and user problems.

William T. Pecora Symposium, hosted by the U.S. Geological Survey, EROS Data Center, (in cooperation with NASA), Sioux Falls, South Dakota 57198.

This annual symposium (since 1975) focuses on demonstrated and potential applications of satellite remote sensing data. The meeting is organized and led by a primary sponsor in a selected technical theme. Past subjects and sponsors have included: Satellite Hydrology, American Water Resources Association; Wildlife Management, National Wildlife Federation; Minerals and Mineral Fuel Exploration, American Association of Petroleum Geologists; and others. Proceedings should be requested from the sponsoring organization.

Bibliographies and Abstracts Lists

Several bibliographies and abstracts of periodical remote sensing literature are available; some have been computerized for access to the literature by key word searches. The more pertinent of these bibliographies and abstracts include:

NASA Earth Resources Program Weekly Abstracts, available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, at an annual subscription rate of $45.00.

This weekly publication provides a list and synoptic descriptions by authors of documents related to Earth resources programs, including Landsat experimental reports available through NTIS. Also, an annual comprehensive listing is available for subscribers.

Scientific and Technical Aerospace Reports (STAR), NASA, Scientific and Technical Information Office, Washington, D.C. 20546 (annual semi-monthly subscription rate: $66.90; cumulative semi-annual index rate: $28.10; available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20420).

STAR publications are a major component of a comprehensive NASA information system covering aeronautics, space, and supporting disciplines. Part 35, "Instrumentation and Photography," and Part 45, "Earth Resources," (remote sensing of Earth resources by aircraft and spacecraft, photogrammetry, and aerial photography), are the Landsat related sections of these reports. The available information includes author abstracts for: NASA and NASA-funded reports; reports issued by other U.S. governmental agencies, universities and private firms; translations; patents; and academic dissertations/theses.

Earth Resources, available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, at an annual subscription rate of $30.00.

This quarterly NASA bibliography includes documents related to the identification and evaluation of vegetation, minerals and other natural resources by means of remote sensing, and the associated techniques and potentialities of surveying and monitoring these resources. Descriptions of the components and use of remote sensing and geophysical instrumentation, their subsystems, observational procedures, signature and analyses, and interpretive techniques for gathering data are also included. This bibliography is helpful to researchers in several disciplines including agriculture and forestry, geography and cartography, geology and mining, oceanography, and environment sciences.

Quarterly Literature Review of the Remote Sensing of Natural Resources, Technology Applications Center, University of New Mexico, Aibuquerque, New Mexico 87131.

This quarterly publication lists the majority of published materials in remote sensing from NASA, NTIS, Engineering Index, and four other data bases. It is subdivided into six categories covering all areas of remote sensing applications and research.

Landsat United States and Non-United States Standard Catalogs, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771.

These catalogs are published monthly and list imagery acquired by the various Landsat satellites which have been processed and input to the data files during the referenced month. Data, such as date acquired, cloud cover and image quality, are given for each scene. The microfilm roll and frame on which the scene is found are also given.

The World Remote Sensing Bibliographic Index, compiled by P. Krumpe, Tensor Industries, Inc., 8415 Arlington Boulevard, Fairfax, Virginia 22030, 1976, 619 pages.

This book is a geographic index bibliography of over 4,000 references on remote sensing of natural and agricultural resources throughout the world. Citations from 1970 to August 1976, are arranged within fourteen major disciplines among more than 150 geographic areas, states, and countries. This extensive compilation originates from more than 850 foreign and domestic sources among six major publishing categories. Instructions for procuring desired publications or reports are included. This book is designed as an integrated reference guide for use in remote sensing and environmental education, training, applications research, analysis, and technology transfer.

Glossaries

Some remote sensing technical publications include a glossary of terms and acronyms specifically discussed in the text; e.g., ASP's *Remote Sensing Manual,* F. F. Sabins' *Remote Sensing Principles and Interpretation.* The following glossary has been written for the non-specialist in remote sensing and presents basic definitions of the terminology involved.

Remote Sensing and Multi-disciplinary Earth Resources Applications Glossary, NASA/ERL, National Space Technology Laboratories, NSTL Station, Mississippi 39529.

This 25-page glossary is designed to assist investigators in various disciplines who are interested in using remotely sensed data in their areas of study. The glossary includes terminology associated with a wide variety of physical and natural sciences that are of significance for a basic understanding and application of remote sensing technology.

Films

NASA has produced an environmental film series under the title of, "Landsat: A Satellite for All Seasons." The six 15-minute films in this series are designed to provide an understanding of the mounting pressures on planet Earth in the areas of food production, land use, mineral resources, environmental quality, and water resources. The use of satellite information and Landsat images in the analysis of these problems is shown vividly in the films along with the hope and assessment of solutions offered by space technology.

For additional information about this film and listings of other similar films, contact the nearest NASA Regional Film Library located at the following addresses:

NASA Ames Research Center, Public Affairs Office, Moffett Field, California 94035 (Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming)

NASA George C. Marshall Space Flight Center, Public Affairs Office, Marshall Space Flight Center, Alabama 35812 (Alabama, Arkansas, Iowa, Louisiana, Mississippi, Missouri, Tennessee)

NASA Goddard Space Flight Center, Public Affairs Office, Educational Programs, Greenbelt, Maryland 20771 (Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania)

NASA John F. Kennedy Space Center, Public Affairs Office, Code PA-EPB, Kennedy Space Center, Florida 32899 (Florida, Georgia, Puerto Rico, Virgin Islands)

NASA Langley Research Center, Public Affairs Office, Mail Stop 154, Langley Station, Hampton, Virginia 23365 (Kentucky, North Carolina, South Carolina, Virginia, West Virginia)

NASA Lewis Research Center, Office of Educational Services, 21000 Brookpark Road, Cleveland, Ohio 44135 (Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin)

NASA Lyndon B. Johnson Space Center, Photographic Technical Lab., Audiovisual Office, Code OL-13, Houston, Texas 77058 (Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas)

National Audiovisual Center (GSA), Washington, D.C. 20409 (Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont)

Legislative Documents

Annual Congressional hearings for NASA appropriations and Congressional committee reports on Landsat related legislative bills provide insight as to proposed Landsat programs and frequently include testimony highlighting recent Landsat data applications. Occasional reports to Congress by the Comptroller General of the United States, General Accounting Office, provide similar information on the status of Landsat programs. Specific documents can be obtained from:

United States Senate
Committee on Commerce, Science and Transportation
Washington, D.C. 20510

United States House of Representatives
Committee on Science and Technology,
Washington, D.C. 20515

General Accounting Office
441 G Street, NW, Washington, D.C. 20548

User Assistance Sources (Federal and State)

EROS Data Center

Applications Branch
EROS Data Center, U.S. Geological Survey
Sioux Falls, South Dakota 57198
(605) 594-6511, FTS: 784-7511

EROS Applications Assistance Facility
U.S. Geological Survey
National Space Technology Laboratories
NSTL Station, Mississippi 39529
(601) 688-3541, FTS: 494-3541

EROS Applications Assistance Facility
U.S. Geological Survey, Geophysical Institute
University of Alaska, Fairbanks, Alaska 99701
(907) 479-7487, FTS: 399-0150
(Seattle operator will connect to Fairbanks number)

EROS Applications Assistance Facility
HQ Inter-American Geodetic Survey
Headquarters Building, Drawer 394
Fort Clayton, Canal Zone
(Ask overseas operator for Fort Clayton 83-3334)

National Cartographic Information Center

Eastern Mapping Center
National Cartographic Information Center
U.S. Geological Survey, 536 National Center
Reston, Virginia 22092
(703) 860-6336, FTS: 928-6336

Mid-Continent Mapping Center
National Cartographic Information Center
U.S. Geological Survey, 1400 Independence Road
Rolla, Missouri 65401
(314) 364-3680, Ext. 107, FTS: 276-9107

National Space Technology Laboratories
National Cartographic Information Center
U.S. Geological Survey, Building 1100
NSTL Station, Mississippi 39529
(601) 688-3544, FTS: 494-35444

National Cartographic Information Center
U.S. Geological Survey, 507 National Center
Reston, Virginia 22092
(703) 860-6045, FTS: 928-6045

Rocky Mountain Mapping Center
National Cartographic Information Center
U.S. Geological Survey, Stop 504, Box 25046,
Federal Center, Denver, Colorado 80225
(303) 234-2326, FTS: 234-2326

Western Mapping Center
National Cartographic Information Center
U.S. Geological Survey, 345 Middlefield Road
Menlo Park, California 94025
(415) 323-8111, Ext. 2427, FTS: 467-2427

National Conference of State Legislatures

Mr. Paul A. Tessar
Director, Satellite Remote Sensing Project
National Conference of State Legislatures
1405 Curtis Street, 23rd Floor, Denver, Colorado 80202
(303) 623-6600

National Governors' Association

Ms. Peggy Harwood
Staff Associate for Natural Resources,
Council of State Planning Agencies
Hall of the States, 444 North Capitol Street
Washington, D.C. 20001
(202) 624-7727

State Agencies (with centralized remote sensing programs)

Arizona

Michael S. Castro
Arizona Resources Information System
1812 West Montore, Suite 202, Phoenix, Arizona 85007
(602) 271-4061

California

Tim Hays
Project Director, Environmental Data Center
Office of the Governor, Office of Planning and Research
1400 Tenth Street, Sacramento, California 95814
(916) 322-3784

Florida

Bill Kuyper
Remote Sensing Engineer, State Topographic Office
Dept. of Transportation, Haydon Burns Building
Tallahassee, Florida 32304
(904) 488-2168

Georgia

Bruce Q. Rado
Georgia Department of Natural Resources
270 Washington Street, S.W., Room 700, Atlanta, Georgia 30334
(404) 656-3214

Idaho

Alan Porter
Division of Budget, Policy Planning and Coordination
State House, Boise, Idaho 83720
(208) 554-3900

Iowa

Bernard Hoyer
Iowa Geological Survey
123 North Capitol, Iowa City, Iowa 52242
(319) 338-1173

Kentucky

John Antenucci
Department of Natural Resources and Environmental Protection
407 Capitol Plaza Towers, Frankfort, Kentucky 40601
(502) 564-2340

Maryland

Tom Rugoski
Department of State Planning, State Office Building, Room 1101,
301 West Preston Street, Baltimore, Maryland 21201
(301) 383-2472

Minnesota

Donald P. Yaeger
Mapping and Remote Sensing Information Center
State Planning Agency
15 Capitol Square Building, St. Paul, Minnesota 55101
(612) 296-1211

Mississippi

Eddie Downing
Research and Development Center
P.O. Box 2470, Jackson, Mississippi 39205
(601) 982-6339

Montana

Thomas Dundas
Remote Sensing Information Systems Division
Department of Community Affairs
Capitol Station, Helena, Montana 59601
(406) 449-8295

New Jersey

Richard Binetsky
New Jersey Department of Community Affairs
P.O. Box 2768, Trenton, New Jersey 08625
(609) 292-8917

New Mexico

Gerald Gates
Department of Fish and Game
Villagra Building, Santa Fe, New Mexico 87503
(505) 827-5446

North Carolina

John Higgins
Department of Natural Resources and Community Development
P.O. Box 27687, Raleigh, North Carolina 27611
(919) 733-2090

Ohio

Garry Schaal
Ohio Department of Natural Resources
Fountain Square, Columbus, Ohio 43224
(614) 466-6557

Oregon

Ken Hansen
Land Conservation and Development Commission
1175 Court Street, N.E., Salem, Oregon 97310
(503) 378-2978

South Carolina

Gerald Minick
South Carolina Land Resources Conservation Commission
2221 Devine Street, Columbia, South Carolina 29205
(803) 758-7197

South Dakota

Dick Gebhart
Land Resource Information System, State Planning Bureau
State Capitol, Pierre, South Dakota 57501
(605) 773-3628

Texas

Samuel McCulloch
Texas Natural Resources Information System
P.O. Box 13087, Capitol Station, Austin, Texas 78711
(512) 475-3321

Vermont

M. Brian Stone
Chief of Project Management,
Department of Forest, Parks and Recreation
Agency of Environmental Conservation, Montpelier, Vermont 06502
(802) 828-3375

Virginia

Robert F. Hutcheson
Department of Agriculture and Consumer Service
203 North Governor St.
P.O. Box 1163, Richmond, Virginia 23219
(804) 786-4712

Washington

Mike McCormick
Office of Community Development, Room 400
Capitol Center Building, Olympia, Washington 98504
(206) 753-2425